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Supporting schemes for renewable energy sources and their impact on reducing the emissions of greenhouse gases in Greece

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Abstract

For Greece the target set by the Kyoto Protocol foresees an increase of greenhouse gases (GHG) emissions by up to 25% for the period 2008–2012, always with respect to 1990 levels. Apparently it is hard to achieve this target, because the current trend of emissions leads roughly to doubling the rate of increase, than to reducing it. Consequently, further support actions are required, in order to enhance the effort needed so that the country will manage to fulfill its commitments.

The present paper aims at the evaluation of the existing situation and the suggestion of further actions required in the energy sector, and particularly in the exploitation of renewable energy technologies (RETs), in order to achieve the obligations that Greece has undertaken as far as the reduction of GHG emissions is concerned, in accordance to the European and international Greek commitments.

Abbreviations: CO_2e, carbon dioxide equivalent; CHP, combined heat and power; CSF, Community Support Framework; EC, European Commission; ES, energy saving; ETS, emissions trading scheme; EU, European Union; GHG, greenhouse gases; MEPPPW, Ministry of Environment, Physical Planning and Public Works; MA OPC, Managing Authority of Operational Programme Competitiveness; NE, non-estimated; NIMBY, not in my back yard; OPC, operational programme "competitiveness"; RES, renewable energy sources; RESe, electricity produced from RES; RET, renewable energy technologies; tCO_2e, tonne of carbon dioxide equivalent

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The current analysis is based on the recent available data from official Greek institutions such as the relevant Ministries, the Managing Authority of the Operational Programme Competitiveness and related European institutions.

Based on the results of the current study the implementation of RETs' investments for the period 2000–2006 is estimated to cover, at best, 50% of the share corresponding to the energy sector for the national target of reducing GHG emissions. In order to achieve to a full extent the target up to 2010, an additional investment cost of some 740 M€ will be needed.

Keywords: Greece; Renewable energy; Kyoto protocol; Greenhouse gases

Contents

1. Aims

Many countries have problems to face their greenhouse gases (GHG) engagements, although they have adopted several—but not enough—support measures. In order to evaluate their up-to-day performance it is essential to get a complete picture of the degree of achievement of these engagements [1].

The present paper aims at the investigation/evaluation of the existing situation and the suggestion of further actions required in the exploitation of the renewable energy technologies (RETs), in order to achieve the obligations that Greece has undertaken as concerns the reduction of GHG emissions, in accordance to the Convention of

United Nations on the Climate Change, the Kyoto Protocol and the European Community Legislation.

In detail these consist of:

- The determination of necessary priorities and the setting of directions in the RET sector so as to achieve the national targets, as well to maximize the exploitation of financing instruments by means of the 3rd Community Support Framework (CSF).
- The elaboration of primary data available from the implementation of RETs investments hitherto, in order to evaluate the path towards the targets set, but also to determine further necessary measures towards these aims.
- The determination of any opportunity profit that will result from the achieving the obligations placed by the Kyoto Protocol, in terms of avoiding the financial penalties due to excessive emissions, apart from the obvious environmental profit.

In order to determine all these targets the analysis is based on the recent, available data from official Greek institutions. These include the Ministry of Environment, Physical Planning and Public Works (MEPPPW), the Ministry of Development, the Managing Authority of the Operational Programme Competitiveness (MA OPC) and related European institutions (Eurostat, European Environment Agency and European Commission).

2. The institutional framework for the reduction of GHG emissions

2.1. Kyoto Protocol

The Kyoto Protocol for the Climate Change determined for the first time legally binding targets for the reduction of GHG emissions and it confirms the need of collaboration within the international community in subjects that concern such a major environmental problem.

Within the framework of engagements that arise from the Kyoto Protocol, the EU has been committed to the reduction of GHG emissions by 8% in the period 2008–2012. The relevant commitments of all EU(15) Member States are presented in Table 1.

Greece ratified the Protocol in 2002 (Law 3017/2002) and adopted a National Programme for achieving the above-mentioned commitment [2]. Besides the 6th Action Plan for the Environment aims at the designation of priorities and targets of the European environmental policy at least up to year 2010, as well as in the analytical determination of measures that should be taken, in order to contribute to the implementation of the EU strategy in matters of sustainable development. The focal point of the 6th Action Plan for the Environment is a four fundamental sectors' action: the climate change, the biodiversity, the environment and health, as well as the sustainable management of resources and wastes.

2.2. Directive on the emissions trading

The EU Emissions Trading Scheme (ETS) is the cornerstone of the European Climate Change Programme as it created a market for carbon dioxide (CO_2) allowances as of 1 January 2005, by supporting the emission reductions where they are most economically efficient [4,5].

Table 1
Allocation of commitments of the EU(15) Member States for the abatement of all six GHGs in the period 2008–2012 in relation to the base year

Luxembourg	−28.0%
Germany	−21.5%
Denmark	−21.5%
Austria	−13.0%
United Kingdom	−12.5%
Belgium	−7.0%
Italy	−6.5%
Holland	−6.0%
France	0%
Finland	0%
Sweden	+5.0%
Ireland	+14.0%
Spain	+15.0%
Greece	+25.0%
Portugal	+28.0%

Source: [2].

2.3. Draft of directive on the joint implementation and the clean development mechanism

The Kyoto Protocol forecasts two further flexible mechanisms, apart from the ETS, namely the Joint Implementation and the Clean Development Mechanism. So, there is a need of integration in the European legislation for two additional flexible mechanisms, in order that the emission credits from the implementation of projects in the framework of Joint Implementation and Clean Development Mechanism can be marketable via the ETS. The basic action that the Member States can undertake in the framework of two mechanisms concerns actions in the energy sector such as, RES systems, substitution of fossil fuels, energy saving, etc.

2.4. Directive 2001/77/EC for the promotion of electricity produced from RES in the internal electricity market

The Member States take the appropriate measures to encourage greater consumption of electricity produced from RES (RESe) in conformity with the national indicative targets. According to Annex of the Directive, by 2010 the participation of RESe on a EU level should be rised to the 22% of gross electricity consumption, while for the case of Greece the relative reference value is 20.1%, the contribution of the large-scale hydroelectric plants being included [3,6].

3. National policies and targets for the reduction of GHG emissions

The national policies and the targets for the reduction of GHG emissions are presented in the National Action Program to reduce GHG emissions 2000–2010 that was elaborated with responsibility of MEPPPW (Official Gazette of the Hellenic Republic 58/A/ 05.03.2003) [7,8].

3.1. The GHG emissions for the years 1990–2000

For Greece the target of Kyoto, even augmentative, is not easy to be achieved given that the spontaneous tendency of emissions leads roughly to double rate of increase. Greece is well above its Kyoto target path. The so-called "distance to target indicator", or difference between actual emissions and target path measured in index units, was +8.7 in the year 2000 [7].

The participation of the productive sectors and the other activities in the total GHG emissions is depicted in Fig. 1. The energy sector is the single most important CO_2 emissions factor. The agricultural sector contributes significantly to N_2O emissions, due to the use of nitrogenous fertilizers, and to CH_4 emissions, due to the uncontrollable disposal of agricultural and stockbreeding wastes. Other important sources of CH_4 emissions are the urban waste disposal areas. Finally, the industry constitutes the unique source of fluoride combinations. In general, the activities related to the use of energy constitute the highest source for GHG emissions, approximately 77.9%, agriculture comes up to 7.9%, industrial processes to 9.9%, waste to 4.1% and the use of solvents to 0.1% [7].

The great share of responsibility of energy sector leads to the conclusion that policies aiming at the reduction of the GHG emissions should primarily and intensively focus on the production, distribution and use of energy, with electricity generation being the obvious main target.

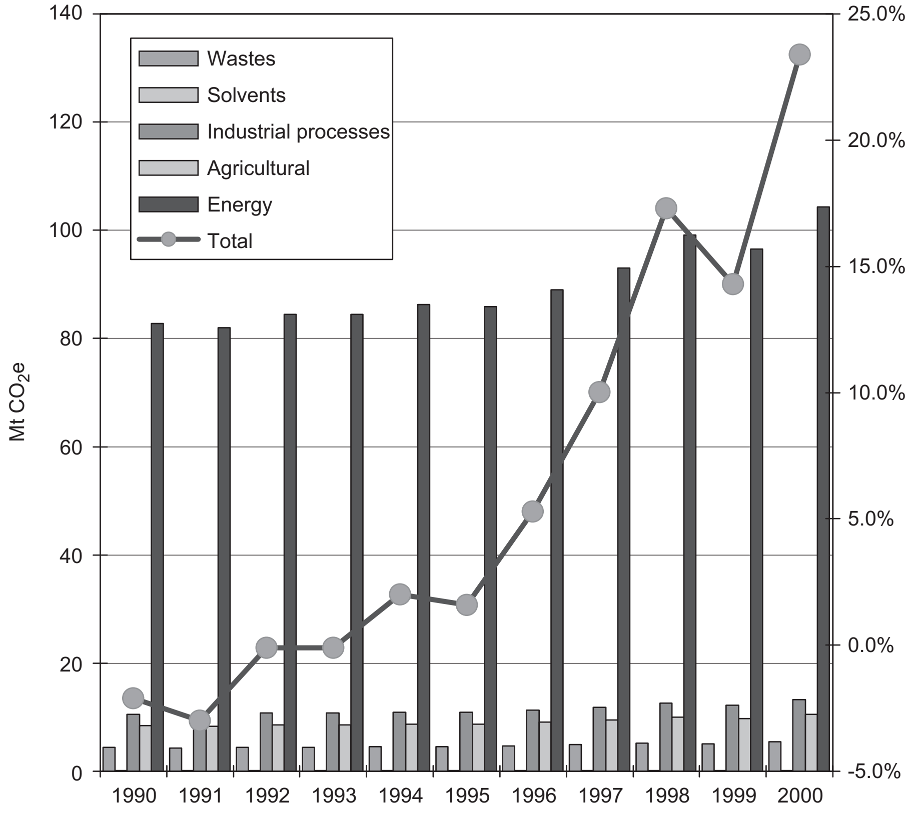

Fig. 1. Total emissions (in ktCO_2e) per production sector.

3.2. Emissions of the energy sector

According to the Greek National Program, the total primary energy demand will increase continuously up to 2020, with an average annual increase rate of approximately 2.1%. The liquid fuels cover the largest part of the primary energy demand (Table 2). However the RES contribution in the total primary energy demand for the entire examined period, will decrease from 4.85% in 1995 to 4% in 2020. This paradoxical development is due to the reduction of biomass use for space heating in the domestic sector, which results from the urbanization of the population and the diminishment of remote rural residences that used mainly wood for heating. The wind and solar energy is forecasted to present remarkable growth in the examined period, while the growth rates for hydroelectric plants are lower.

The energy sector in Greece is based on the use of fossil fuels, namely lignite, with a respectively significant impact on the emissions of pollutants and particularly GHG (Table 3). We observe an increase of CO_2 emissions from the energy sector by 45% in 2010 and by 65.6% in 2020, concerning the 1990 levels. With regard to CH_4 emissions, the sectors of transport and industry constitute the most important sources, while total CH_4 emissions are expected to present a small reduction after 2000, with an average annual rate of approximately 0.8%. Finally, the electricity sector constitutes the main source of N_2O emissions, while total N_2O emissions are to increase with an annual rate of about 1.3% for the next 20 years (Table 3).

3.3. Suggested interventions for GHG emissions

There are two groups of technology options to reduce GHG emissions from power production:

- Shifting energy resources mix towards with lower GHG and specifically CO_2 emissions per MWh_e.
- Improvement of generation efficiency.

Table 2
Total primary energy demand in Greece (ktoe)

	Primary energy demand (ktoe)						Annual increase (%)		
	1995	2000	2005	2010	2015	2020	1995/2000	2000/2010	2010/2020
Solid fuels	8386	8756	8894	9192	9462	9672	0.87	0.49	0.51
Liquid fuels	14,117	15,981	17,023	18,353	19,441	20,651	2.51	1.39	1.19
RES	1152	1350	1308	1355	1434	1606	3.22	0.04	1.72
Natural gas	49	1731	3655	5148	6672	8037	104.01	11.51	4.55
Electricity	69	−0.9	0.4	0.4	0.4	0.4			
Total	23,773	27,817	30,880	34,048	37,009	39,966	3.19	2.04	1.62
RES penetration (%)	4.85	4.85	4.24	3.98	3.87	4.02	0.03	−1.97	0.10
Energy intensity (ktoe/M€)	0.23	0.23	0.21	0.19	0.18	0.17	−0.12	−1.81	−1.30
Energy consumption per capita (toe/cap)	2.26	2.56	2.77	2.99	3.2	3.42	2.53	1.57	1.36

Source: [6].

Table 3
Evolution of the GHG in the Greek energy sector ($ktCO_2e$)

Sector	Pollutants	1990	1995	2000	2005	2010	2015	2020
Total	CO_2e	79,859	83,357	99,890	106,635	115,676	123,929	131,950
	CO_2	76,474	79,778	95,682	102,083	110,838	118,866	126,647
	CH_4	316	342	456	403	394	392	400
	N_2O	3069	3237	3752	4149	4444	4671	4903
Electricity production	CO_2e	42,910	44,570	53,747	55,360	60,490	65,378	70,214
	CO_2	41,202	42,746	51,702	53,199	58,141	62,877	67,564
	CH_4	6	7	8	18	19	20	20
	N_2O	1702	1817	2037	2143	2330	2481	2630

Source: [6].

Both options are constrained by factors that influence technological developments, like efficiency of the technology, cost and the rate of renewal of power plants. A schematic description of the problem is depicted in Fig. 2. The balance of capital and operational costs, mainly fuel costs, determines generation efficiency: efficiency increases as fuel cost increases, and efficiency increases as capital cost decreases. Hence policy approaches could work along both these axes: economic instruments to increase fuel costs or costs of emitting CO_2 and other GHG; technology support programmes to reduce the capital cost of more efficient technologies [9–11]. Competition in the electricity supply, as it is expected to occur after 2007 and the full liberalization of the Greek electricity sector, will contribute to both aims, as minimizing fuel cost and other operating costs through efficiency improvements is essential in a competitive environment. Competition, furthermore, promotes a search for new technologies in order to gain a cost advantage.

According to the National Action Program to reduce GHG emissions, a group of actions is foreseen to be implemented until 2010. The main actions foreseen by the program include:

- Further penetration of natural gas in all the sectors of final demand including combined heat and power (CHP) systems.
- Promotion of RETs in the production of electricity and heat.
- Energy saving in the industrial sector, as well as in the domestic and tertiary sector.
- Promotion of energy efficient appliances and equipment in the domestic and tertiary sector.
- Structural changes in the agriculture and in the chemical industry.

The complete implementation of these measures will lead (considering their full implementation and not taking into consideration synergies appearing between them) to the reduction of emissions at 18.2 Mt CO_2 equivalent (CO_2e), with result the reduction of increase of GHG emissions in the +19% concerning the emissions of the reference year.

The two main axes of action of the National Program, the implementation of which will determine its success, are:

- The promotion of RET, both on the level of final energy demand and on the level of electricity generation, with an estimated potential of emissions' reduction in the magnitude of 6.4 Mt CO_2e.

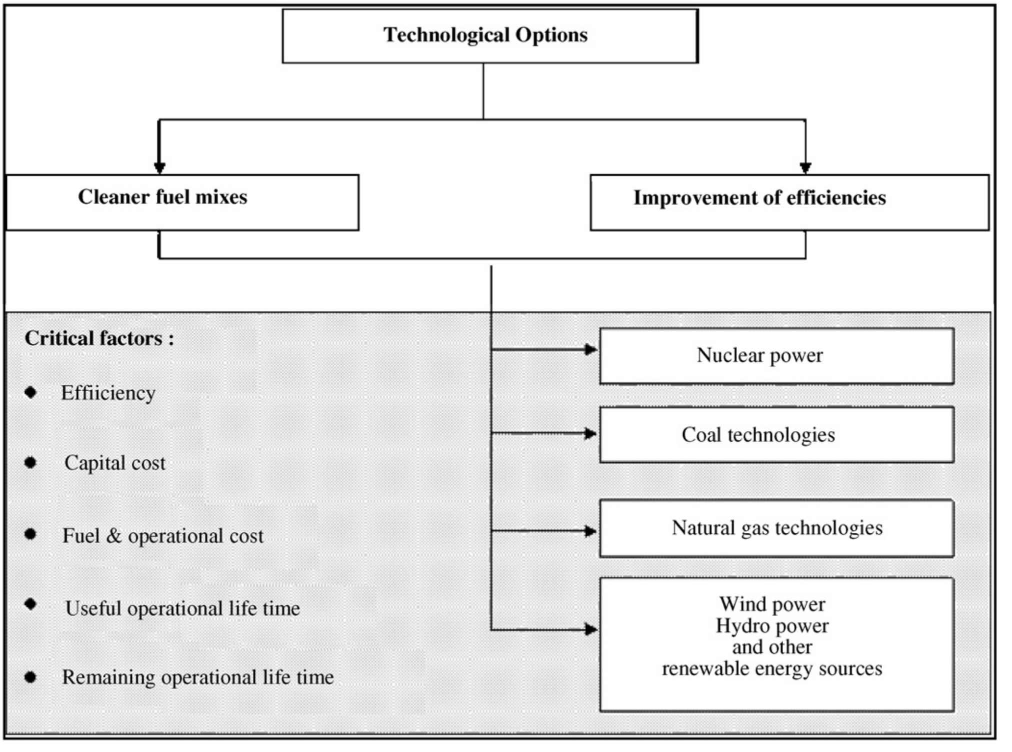

Fig. 2. Technological options and factors for reducing GHG emissions.

- The further penetration of natural gas in the national energy system, a policy that will contribute in the additional reduction of emissions by 3.9 Mt CO_2e.

The complete implementation of the planned measures is an undertaking of considerable difficulties, whilst possible diversions from the plan will result in failing to meet the targets set for Greece by the Kyoto Protocol. Considering therefore as a realistic degree of implementation of the afore-mentioned interventions at the order of 70%, with the exception of measures that concern emissions f-gases (HFCs, PFCs, και SF_6) , and taking into consideration the synergies from the simultaneous implementation of various measures, it is estimated that:

- The total reduction of GHG emissions possible to be achieved amounts to 12.3 Mt CO_2e.
- The increase of emissions in 2010, concerning the 1990 level, is estimated to be at the level of +24.5%, an increase that would cope with the requirements foreseen within the framework of the Kyoto Protocol.

From the cost estimation of the proposed interventions resulted that, the complete implementation of interventions for the reduction of GHG emissions requires the allocation of important financial resources, the amount of which is expected to reach 7.7

G$, in constant 1997 prices. The average unit cost of reduction of GHG emissions at 12.4% is calculated to be 13.5 $/t$CO_2$e, i.e. for each avoided CO_2 tonne.

4. Contribution of the OPC in the promotion and dissemination of RET

A main instrument for the promotion of the National Program, and the achievement of its implementation, is the 3rd CSF 2000–2006. However it has to be taken into account that the schedule of the two programs differ, 2006 being the deadline for the 3rd CSF and to 2012 for the National Program. Thus, the 3rd CSF can constitute the basic instrument for the take-off of the reduction program of GHG emissions, but it has to be assumed that by the time it is finished, appropriate policies will have become effective, which will ensure the continuation of the National Program.

4.1. Third CSF 2000–2006

The 3rd CSF constitutes a powerful instrument for the development, the social cohesion and the modernisation of Greece. Its goals are the continuation and the enhanced support of policies for the real convergence of Greece and the older EU Member States, the regional development and the social cohesion (Table 4).

Emphasis is given in investments for infrastructure projects, which are essential for the rational use and management of environmental resources. Moreover, the monitoring of environmental obligations, to which the country is committed, is also recognized as an important priority in policies within the sustainable axes action.

Amongst the National Operational Programs one of the most significant ones is the "Operational Programme Competitiveness" (OPC), covering four basic sectors of the economy, namely manufacturing and services, energy and natural resources, research and technology and tourism.

4.2. OPC

The OPC is financed by the European Fund of Regional Development and the European Social Fund. The total cost of the Program is 6392.3 M€, from which the community financing accounts for 31%. The national public expense constitutes 19.4% of the total cost, while the private sector participates with 49.6% of it.

The OPC is structured in 9 action priorities; each priority is divided into further measures; each measure is subdivided into actions and those again into projects, with the latter featuring common orientation and relevant objects.

As far as the energy sector is concerned, the OPC has been considered as the means to achieve the modernization of the Greek energy system, the improvement of the national economy's competitiveness, the monitoring and targeting of the country's environmental engagements.

The increased and more efficient utilization of domestic energy resources, such as RET and CHP systems, as well as the effort to reduce the energy intensity, which is amongst the highest in the EU(15) is expected to contribute considerably both to the guarantee of energy supply and to the environmental protection. Furthermore, it is by now an established fact that both the RET development and the implementation of energy saving

Table 4
The goals of the 3rd Community Support Framework

Main goals

- The continuation and the enhanced support of policies for the real convergence of Greece and the older EU Member States
- The regional development
- The social cohesion

Specific goals

- The improvement of human potential (education, creation of effective structures of professional training and continuous education)
- The strengthening of productivity and competitiveness as fundamental factors for the establishment of economic and social growth
- The new technologies, which constitute a strategic instrument for competitiveness in the globalized markets; it is dealing with the increasing problem of development of mechanisms of creation, absorption and exploitation of innovation and advanced know-how
- The modernisation of the productive sector of the Greek economy, including tourism and agriculture
- The protection of natural resources and the improvement of living quality, through productive reforms and the off-set of negative side-effects of growth in the past
- The promotion of Greece's cultural heritage that can constitute a major argument for the attraction not only of tourism, but also of business capital and executive branches
- The reduction of public involvement in terms of investments in the projects, which can be carried out by the private sector, whilst maintaining the necessary guarantees for the public interest

measures contribute considerably to the regional development and to the creation of new jobs, especially in remote and insular regions level [2,12].

In that sense, and within the scope of this paper, it is important to notice that a not insignificant number of OPC actions is dedicated to the promotion of RET. This is depicted in Table 5, with the corresponding budgets for the various actions. One can observe that Action 2.1.3, i.e. the promotion of RET, constitutes 78% of the OPC actions of OPC. This is expected to contribute directly, indirectly or as a supporting measure to the reduction of GHG emissions and act as an extension of the effort to achieve the commitments of the country within the framework of the Kyoto Protocol and, at the same time, as a main tool for the increase of RET penetration in the energy system, according to the requirements of the Directive 2001/77/EC.

These actions, as well as the quantification of reduction in GHG emissions resulting from OPC's implementation is, are presented in detail in the following paragraph.

4.3. Estimation of the reduction of GHG emissions from the implementation of RET investments

Action 2.1.3, "Economic incentives for the aid of individual private energy investments," constitutes a basic instrument for the promotion of energy efficient and environmental friendly investments in the energy sector and it is expected to contribute directly to the fulfillment of the country's commitments in various sectors (Table 6).

The investments that are implemented within the framework of the program should concern mature technologies only, excluding systems that are in stages of research and

Table 5
OPC actions promoting RES

No	Title	Total budget (€)
Action 2.1.1	Information, support, promotion and dissemination of CHP, RES and ES	4,728,000
Action 2.1.2	Expansion of the technical support infrastructure in CHP, RES and ES	4,000,000
Action 2.1.3	Economic incentives for the support of private energy investments	986,796,833
Action 2.1.4	Special status for the support of energy investments	76,480,788
Action 3.1.1	Applications of demonstration projects of innovative technologies	5,428,370
Action 3.1.2	Identification of the credibility and efficiency of energy equipment and energy products	2,285,630
Action 6.3.2	Projects for the promotion of innovative solutions	55,009,690
Action 6.3.3	Projects to support the transmission and projects to expanse/enforce the grid in islands	4,000,000
Action 6.3.4	Projects to support and to expand the grid connected system of the transmission and distribution	118,000,000
Action 6.3.5	Definition of the geothermal potential of Lesvos Island	7,806,310
Action 7.3.6	Support of the engagements of environmental commitments	1,761,000
Total budget		1,266,296,621

Source: [13].

development, while their implementation has to be completed by the end of 2006, though a brief extension of one year is possible. The relevant categories of investments are:

- energy saving in existing enterprising units;
- cogeneration of electricity and heat or refrigeration;
- substitution of electricity in existing enterprises;
- wind generation systems;
- applications of geothermal energy;
- small hydroelectric plants;
- centralized solar thermal systems;
- exploitation of biomass;
- photovoltaic systems and
- passive solar systems.

The detailed estimations of the expected results of Action 2.1.3 are based on the budgets of the call-for-proposals, on the signed contracts of energy investments up to September 2004 and on the additional financing of the Action by means of the performance reserve available for specific purposes to the Ministry of Development. In Table 7 are presented the budgets of the contracted projects per category of energy investment.

As mentioned afore, one of the two main action axes of the National Program is the promotion of RET, both in terms of covering final energy demand and on the level of electricity generation, with an estimated total potential of emissions' reduction of 6.4 $MtCO_2e$. The analysis that follows, aims at the estimation of reduction of GHG that

Table 6
Main targets of the Action 2.1.3, "Economic incentives for the aid of individual private energy investments

- The guarantee of energy supply and alleviation of dependence from imported primary energy forms via the differentiation of energy sources of supply
- The increase of Greek added value, and the improvement of competitiveness of Greek economy by means of the modernisation of enterprises, the incorporation of environmental dimensions in the operation of enterprises, as powerful and constant means of improvement of their competitiveness and the reduction of final energy cost in the industrial, tertiary and public sector
- The environmental protection and the achievement of the Kyoto commitments, to the degree in which the penetration of RET and energy savings will substitute conventional fuels
- The strengthening of economic activities, regional development and employment. The implementation of RET investments on a regional level, where there is a significant potential, will improve the enterprising and environmental conditions and, moreover, the emerging need for installation, operation and maintenance of such systems provides the background for an increase of the regional employment

Table 7
Contracted energy investments budget (September 2004)

Investment category	Number of projects	Budgets (€)	Allocation (%)
Energy saving	87	182,328,581	26.7
CHP	5	77,789,327	11.4
Electricity substitution	13	3,091,262	0.5
Wind	33	318,042,901	46.6
Geothermal	0	0	0.0
Small hydro	19	60,153,302	8.8
Central solar thermal systems	8	2,311,331	0.3
Biomass	12	23,431,056	3.4
Photovoltaic	4	13,899,947	2.0
Passive systems	3	840,549	0.1
Total	184	681,888,256	100

Source: [19].

will result from the implementation of investments in RET projects, supported by the OPC. In doing so, following assumptions were made:

- The time-scale of the current analysis is up to 31.12.2006, i.e. the date of completion of investments according to the call-for-proposals, not considering possible extensions.
- Investments in energy-saving measures, CHP systems and energy substitution measures will not be taken into consideration, because despite the fact that they contribute to the reduction of GHG emissions, they do not constitute RETs as such.
- For the calculations carried out, and in order to ensure compatibility with other approaches, the RETs indicators are used [15,16].

All these used indicators are depicted in Table 8; in Table 9 are presented the total results estimated for the reduction of GHG emissions due to the implementation of investments in RET. According to these data, the implementation of investments in RET projects, will cover annually 24% of the target, namely the reduction by 6.4 $MtCO_2e$, as this has been expressed in the National Program for the reduction of GHG emissions.

Table 8
Used indicators and assumptions used per RET

(i) *Wind energy*

- The average value of annual reduction of CO_2 emissions from wind energy systems is 600 tCO_2/GWh
- For the wind generators the average value of hours of operation per year (in the productive phase) lies between 6000 and 7000 h/year. This value coincides to a good degree with data applicable to Greek mainland and islands [20]
- Applying the previous indicators to the installed power of 360.30 MW, from the contracted investments in the wind systems, by mid 2005, the annual reduction of GHG emissions are 1405.2 kt CO_2. The respective figure for the end of 2005 is 480 MW, but this an unofficial one [18]. In any case, the respective CO_2 figure would increase in a linear way
- Of interest is also the value of the indicator "turn-key cost of the investment" that varies between 770 and 1000 €/kW, being in line with most similar investments in Southern Europe

(ii) *Small hydroelectric plants*

- The average value of annual reduction of CO_2 emissions due to small hydroelectric projects is 3200 tCO_2/MW
- Applying the previous indicator to the installed power of 45 MW, from the contracted investments in small hydroelectric projects, the annual reduction in GHG emissions are some 144 kt CO_2
- Examining the value of the indicator "turn-key cost of the investment" one can notice that this varies between 600 and 2000 €/kW for installations rated between 1 and 10 MW, between 1300 and 4500 €/kW for smaller installations, rated between 0.5 and 1.0 MW and between 1500 and 6000 €/kW for small installations of less than 0.5 MW.

(iii) *Solar thermal systems*

- The average value of annual reduction CO_2 emissions from Solar Thermal Systems is 840 kg CO_2/m^2, whereby the reference area is the collector's surface
- Applying this indicator to the installed collectors' surface of 7510 m^2, from the contracted investments, results an annual GHG emissions' reduction of 6.3 kt CO_2. It has to be noted that this figure refers to centralized systems only
- The value of the indicator "turn-key cost of the investment" varies between 300 and 500 €/m^2

(iv) *Photovoltaics*

- The average value of annual reduction of emissions CO_2 due to photovoltaic systems is 0.6 kg CO_2/kWh
- The average annual value of energy production from photovoltaic systems for countries of Southern Europe varies between 1000 and 1400 kWh/kWp
- Applying this indicator in the installed power of 1869 kWp from the till now contracted investments in photovoltaic systems, results an annual reduction in GHG emissions of 1.6 kt CO_2
- The value of the indicator "turn-key cost of the investment" varies between 4.30 and 9.50 €/Wp

With respect to photovoltaics it has to be noted, that the legislation valid until April 2005 foresees a very low buy-back rate, of some 0.078 €/kWh. This is the main reason for the almost negligible interest in PV's. The new law regulating the buy-back rates for RET is expected to raise this figure to 0.45 €/kWh, providing, after all, a reasonable rate

(v) *Passive solar systems*

For the scope of this paper the implementation of relevant investments in not considered in the estimation of GHG emissions' reduction; in any case, the part of the OPC budget that corresponds to contracted projects in passive solar systems is 0.1%. One can therefore safely assume that these projects will not have an important impact on the reduction of GHG emissions

Table 9
Estimation of the reduction of GHG emissions due to RES investments contracted by September 2004

Investment category	Estimation of CO_2 reduction (kt)
Wind	1405.2
Geothermal	0
Small hydros	144.0
Solar thermal systems	6.3
Biomass exploitation	NE
Photovoltaics	1.6
Passive solar systems	NE
Total	1557

NE: non-estimated.

In Figs. 3–5 are presented the distribution of RET investments with respect to their regional location, the investment cost, the number of projects and the installed power for the wind and hydro project; we observe that the Peloponnese is the leading region. This may seem unexpected, but one has to keep in mind that the climatically most favorable regions, at least as far as wind power is concerned, of Thrace and of southern Euboea, face the problem of grid connections and are not expected to be able to host significant generation capacity before 2010. The same limitation applies, obviously, also to the most favorable region in Greece, the Aegean Islands.

In Fig. 6 is presented the distribution of the expected time of completion of the energy investments, within the implementation period of the 3rd CSF (2000–2006). We observe that serious delay are monitored in the first years, resulting in the necessity to accomplish the work accumulated in 2006, or—in the case of an extension—by 2008. These serious delays are mainly due to the following causes:

- The long-lasting procedures for the acquisition of the essential licenses for production, installation and operation.
- The delay in the implementation of infrastructure projects concerning the transmission networks as part of the national electricity grid.
- In the not in my back yard (NIMBY) syndrome and in the reactions of residents in few but critical regions, like the southern Peloponnese.

As the licensing processes have been simplified to some degree and the work of interconnection with the grid began to gain momentum, it can be expected that at least a good part of the delays will be made good until 2008 [17,18].

4.4. A forecast on the reduction of GHG emissions from the acceleration of the process

In order to obtain a complete picture of OPC's contribution to meeting the GHG emissions' reduction goals a forecast was carried out, in order to estimate the course of investment projects in RETs by the end of 2006. For the distribution of the remaining available budget of the call-for-proposals it has been assumed that this will done following the same algorithm per category of investment, as this has been done so far, according to the policy followed by the Ministry of Development. Furthermore, the additional sum of

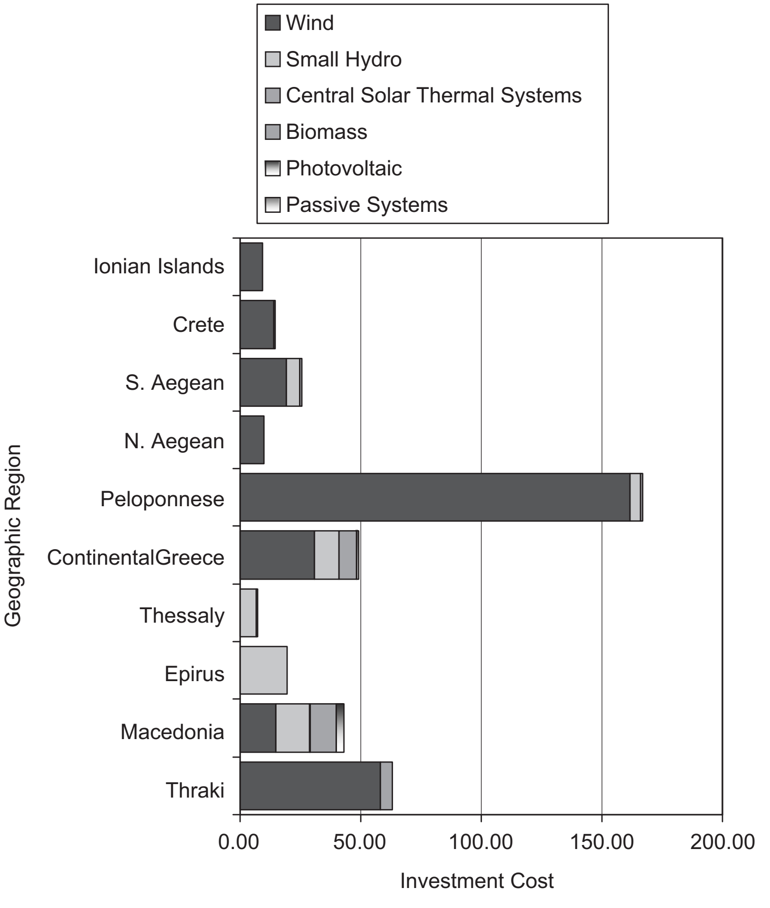

Fig. 3. Allocation of RETs investments per geographic region and investment cost.

220 M€ in the Action 2.1.3 from the performance reserve of OPC, will be allocated, in accordance to the revised OPC program, for investments in wind generation systems. Based on the aforementioned EC data, but also on current cost figures from the RET systems' market, are calculated the forecasted reduction of GHG emissions until 2006 (Table 10). For the calculation in various RETs were considered the values of the Table 11.

The implementation of investments in RET projects up to the end of 2006 is estimated to reach 3.2 $MtCO_2e$, covering roughly 50% of the 6.4 $MtCO_2e$ target as placed by the National Program for the reduction of GHG emissions, which may be reminded that has to be achieved by 2010.

In Fig. 7 is presented the budget allocation per category of project with respect to the RET that will be financed by the 3rd CSF via the OPC in the period 2000–2006.

4.5. Economic impacts from not achieving the target

According to the Directive 2003/87/EC for the ETS, the financial penalties for each tCO_2e that exceeds the annual sum of allowances is 40 €/tCO_2e for the period 2005–2007, while after

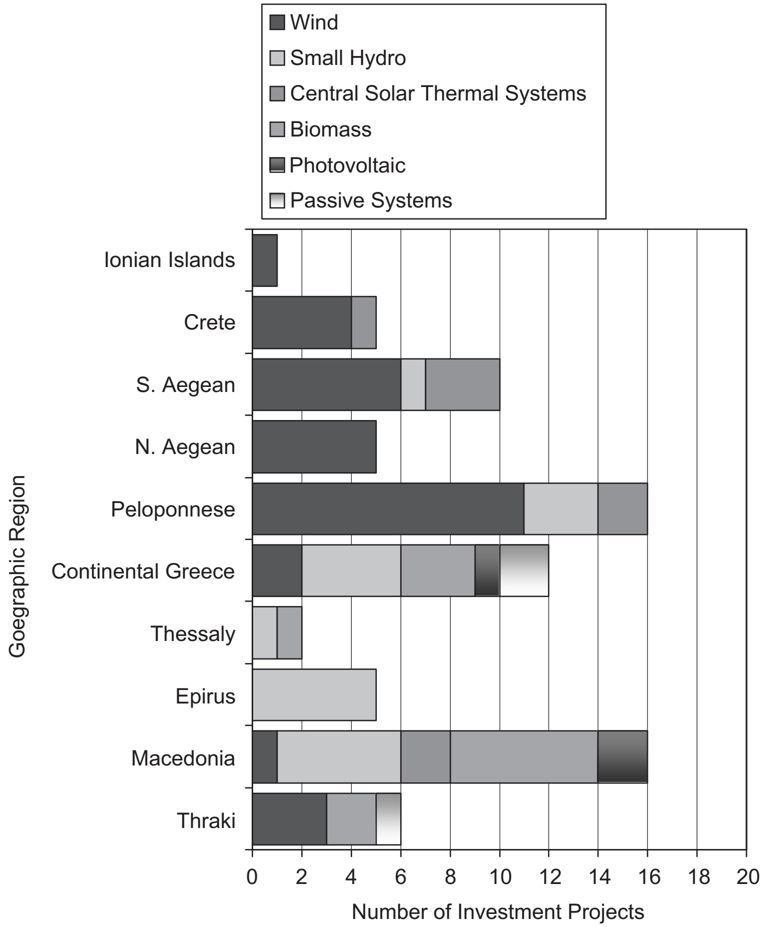

Fig. 4. Allocation of RETs investments per region and number of investment projects.

2008 the penalty will increase to 100 €/tCO_2e [4]. Therefore, for the period 2007–2010, the annual cost for the 3.2 MtCO_2e from not achievement the target is 128 M€ for the period 2006 until 2007 and 320 M€ for 2008 and afterwards. For the whole period 2007–2010 the financial penalty for exceeding the allowances for emissions will amount to approximately 1088 M€.

Considering the figures mentioned in the previous paragraphs, the RET projects implemented in the period 2000–2006 will cover approximately 50% of the national target of 6.4 MtCO_2e annual reduction of emissions. The cost of these RET investments during this period is estimated to be 824 M€ whilst the financial penalty for the country that will correspond for the specific time period and for missing to achieve the foreseen reduction is approximately 768 M€.

It has to be noted, that for the calculations of the required energy investments in order to achieve even this 3.2 MtCO_2e of annual reduction in GHG emissions the following assumptions were made, and have therefore to be fulfilled in practice:

- The new energy projects will concern energy production from wind energy systems only.

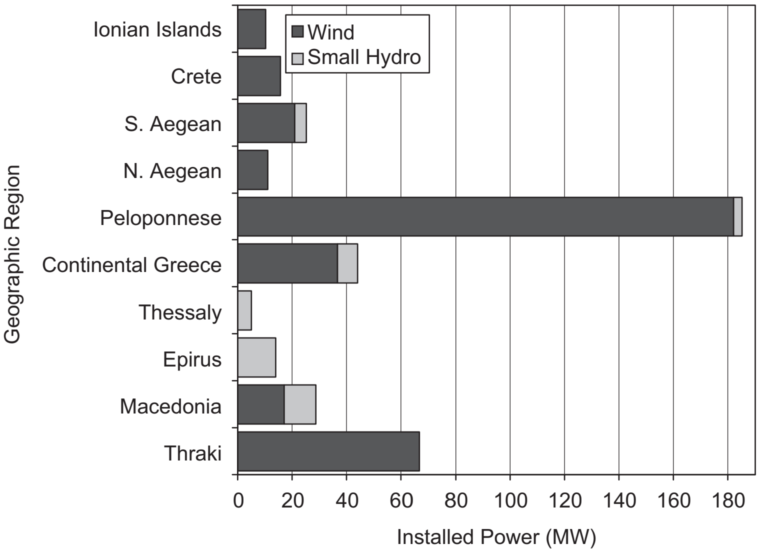

Fig. 5. Allocation of investment of wind and hydro projects per region and installed power.

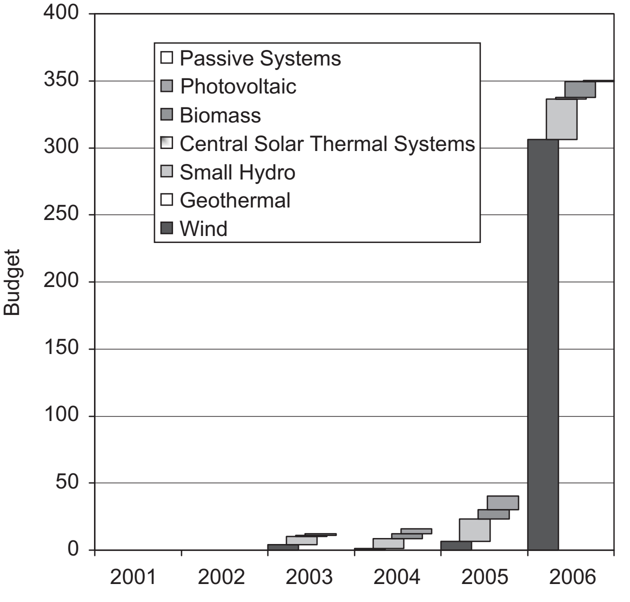

Fig. 6. Time allocation of the completion of energy investments.

- The cost and the performance features of the wind generators will be at least as good as those assumed in the analysis.
- The licensing procedures will indeed be accelerated.

Table 10
Forecasting of CO_2 reductions (kt) till 2006

Investment category	Allocation (%)	Forecasting of budget allocation (€)	Budget per budget per category (€)	Forecasting of CO_2 reduction (kt)
ES	26.7	80,546,189	262,874,770	NE
CHP	11.4	34,364,518	112,153,845	NE
Energy Substitution	0.5	1,365,608	4,456,870	NE
Wind energy	46.6	140,499,879	678,542,780	2940
Geothermal energy	0.0	0	0	0
Small hydro	8.8	26,573,559	86,726,861	231
Solar thermal	0.3	1,021,063	3,332,394	9
Biomass	3.4	10,350,995	33,782,051	NE
Photovoltaic	2.0	6,140,495	20,040,442	2
Passive solar	0.1	371,324	1,211,873	NE
Total	100	301,233,630	1,203,121,886	3183

NE: non-estimated.

Table 11
Values of indicators for the calculation of the reduction expected from various RET investments

(i) *Wind energy*
- Turn-key investment cost of 900 €/kW
- For the wind generators average value of hours of operation per year (in the productive phase) 6500 h/year
- Average value of annual reduction of emissions 600 tCO_2/GWh

(ii) *Small hydroelectric plants*
- Turn-key investment cost of 1200 €/kW
- Average value of annual reduction of emissions 3200 tCO_2/MW

(iii) *Solar thermal systems*
- Turn-key investment cost of 300 €/m^2 of solar collector
- Average value of annual reduction of emissions 840 kg CO_2/m^2 of collector's surface

(iv) *Photovoltaic systems*
- Turn-key investment cost of 7.50 €/Wp
- Average annual value of energy production from photovoltaic systems of 1400 kWh/kWp
- Average value of annual reduction of emissions 0.6 kg CO_2/kWh

In Table 12 and in Fig. 8 are depicted the cost of the implementation scenario, as well as the cost of not doing so, for the energy investments in RETs considered.

It can be observed, if the implementation scenario is to take place, apart from the environmental benefit and profit for the period 2007–2010, a serious financial profit will be achieved, of the magnitude of some 350 M€.

Furthermore it can be observed, that for the period 2000–2006 the cost of not reducing the emissions CO_2e is smaller than the cost of investments, because for this specific period the price for exceeding the emissions' allowances was low (40 €/tCO_2e). This consideration

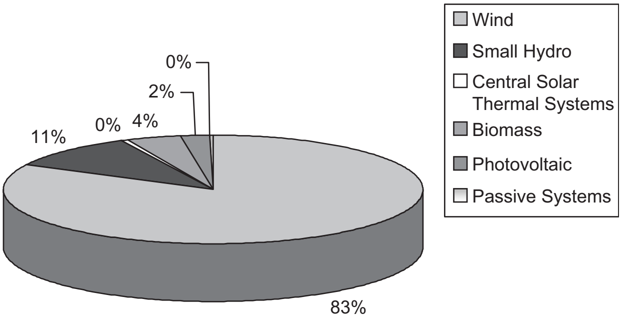

Fig. 7. Budget allocation per category of RETs projects.

Table 12
Estimation of economic impact from the realization of RETs investments

	Investment cost in RES (M€)	CO_2e emissions cost (M€)
2000–2006	824	768
2007–2010	738	1088

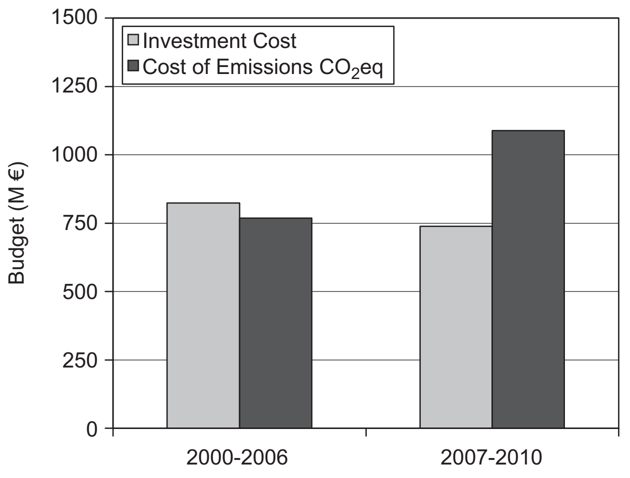

Fig. 8. Estimation of economic impact from the realization of RETs investments.

might have been one of the underlying reasons for the sluggish start of the RET investment in the years of the ongoing decade.

5. Concluding remarks

The projections based on existing national EU-15 policies and measures show that GHG emissions in 2010 will only be 0.6% below base-year levels, 7.4% distance form the Kyoto

target [1]. The additional MS measures promoting RES power generation, CHP and energy efficiency has a potential to reduce this gap by 4.0%.

Especially for Greece the target set by the Kyoto Protocol foresees an increase of GHG emissions by up to 25% for the period 2008–2012, always with respect to 1990 levels. Apparently is will not be easy to achieve this target, because the current trend of emissions leads roughly to doubling the rate of increase, than to reducing it. Consequently, further actions are required, in order to enhance the effort needed so that the country will manage to fulfill its commitments.

During the period 1990–2000, the GHG emissions followed closely the development of GDP, implying that the economic enlargement is accompanied by a corresponding increase in the use of energy and a further increase of the threat imposed to the environment, on a regional and national level, but even beyond that. In order to achieve the uncoupling of economic enlargement and GHG emissions it is required to intensify the efforts to improve, restructure and even remodel the energy sector, which bears the bigger share of responsibility for CO_2 and other GHG emissions.

Energy consumption in Greece presents a steady rise during the last two decades, mainly due to transport and the building tertiary sector, with growth rates exceeding the EU(15) average and being comparable only to those of Spain, Portugal and Ireland. This trend is to a large extent justified, since the per capita energy consumption in Greece is still between the lowest in the EU(15), which is connected directly with the divergence between the economic growth in Greece and in the more wealthy Member States. However, the energy sector in Greece presents a rather poor efficiency, which is mainly due to the dependence on 'traditional' domestic resources, like lignite. Furthermore, even in terms of final demand, Greek buildings are rather inefficient in terms of presenting a disproportionately high heating and cooling demand, specifically. The continuing dependence on oil can hardly be easily addressed, considering the transport sector. On the other hand the introduction of natural gas to the national energy system is expected to improve the situation, substituting both lignite in power generation and oil for heat generation. Still, there is a long way to go towards the main targets, namely reducing energy consumption for the same useful output, using cleaner energy forms and increasing the exploitation of RETs.

The OPC, within in the framework of the 3rd CSF (2000–2006), constitutes a powerful financing instrument for the implementation of RETs investments. Unfortunately, from the experience of the previous decade, the development of RETs was faced rather as a necessary evil within the framework of a vague energy–environmental policy, and not as a real industrial sector that can contribute to economic growth. It is characteristic that after one decade of powerful incentives (L.2244/94, OPE, Development Law) the installed power of RETs in Greece remains low, compared to some EU countries, despite the abundant solar and wind potential.

In this line of thoughts, serious delays were observed during the first years of application of the OPC, concerning the implementation of energy investments. The main causes for this state of affairs were:

- the complex legislative framework, that led to long-lasting processes for obtaining the installation, production and operation licenses;
- the delay in the implementation of infrastructure projects concerning the transmission grids;

- the not in my back yard syndrome and the reactions of residents in certain regions and
- a frequently short-sighted policy by many entrepreneurs, who were unwilling to abolish the 'business as usual' mentality.

Evaluating the RETs' investment projects that have been proposed for implementation and already carried out one can notice an explicit preference for wind energy systems. This precedence will rather continue due to the excellent wind potential, the excellent cost–benefit ratio of state of the art wind generators and the favorable buy-back rates provided by the state. The same will probably apply to photovoltaics after the new legislation.

The implementation of RETs' investments for the period 2000–2006 is estimated to cover, at best, 50% of the share corresponding to the energy sector for the national target of reducing GHG emissions. In order to achieve to a full extent the target up to 2010, an additional investment cost of some 740 M€ will be needed. This could possibly be co-financed by the 4th CSF.

Still, and considering the aforementioned problems and the analysis presented in the previous paragraphs, it is rather improbable that the target will be met on time.

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